INTERNATIONAL JOURNAL OF ELECTRONICS; MECHANICAL and MECHATRONICS ENGINEERING Vol.3 Num 4 pp.(625-630)

A STUDY ON THE APPLICATION OF THE ECAP TO SURFACE PLATING

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ABSTRACT

Metal forming processes with shear stresses that very high plastic strains are obtained in one pass are defined as severe plastic deformation (SPD) processes. Strain values can additionally be increased with additional passes throughout the process. Equal channel angular processing (ECAP) is the most applied method among the SPD processes. In the presented study, an approach of application of ECAP method was used in surface plating. Previously manufactured ECAP dies using separated die design approach were used in the study. 5083 Aluminum and Ms 58 Brass alloy strips having 2 and 4 mm thickness were placed in the ECAP die side by side and processed with single and double passes in order to model the metallic plating under cold pressure welding conditions. There were no successful and full joints between the strips although some partial joints were observed. The results were discussed and some suggestions are made in order to obtain successful joints.

Key Words: ECAP, Separated Dies, Cold Pressure Welding, Plating, Material Tests

1. INTRODUCTION

Regarding the plastic deformation processes, the severe plastic deformation method (SPD) is the most effective way to obtain high strength increase and especially grain size refinement by relatively simple dies and die arrangements due to very high deformation ratios. In these types of processes, deformations up to 100 percent or higher levels can be obtained by relatively simple dies and die arrangements even in single pass [1, 2, 3]. On the other hand, additional repeats of the passes mean multiplication of the deformation. Overall deformation amounts can therefore be raised to very high ratios [3,4]. In equal channel angular pressing (ECAP), entrance and exit cross sections of the material are same but there is an angular difference between them[1, 2] as it is shown in figure 1.

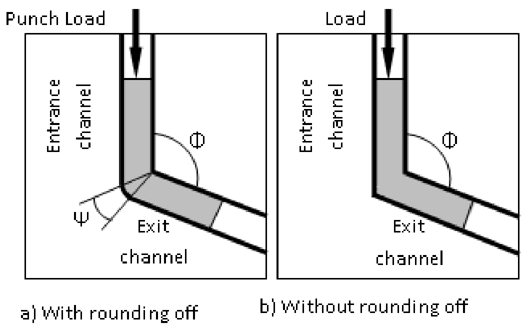

Figure 1. Basic die geometry and process parameters for the ECAP processes.

In classical ECAP applications entrance and exit cross sections are produced as square in shape, and the dimensions vary according to the available press loads, punch length, material properties and frictional conditions. Equal channel dimensions permit the specimen repeatedly be deformed in order to obtain higher strain values. The average strain value obtained in one pass is calculated as follows[1,2,3]:

$$\varepsilon = (1/\sqrt{3})[2(\cot((\Phi/2)+(\Psi/2)) + \Psi \operatorname{cosec}((\Phi/2)+(\Psi/2))] \qquad (1)$$

If there is no curvature between the channels (Fig. 1b), Ψ becomes zero and considering the number of the passes as N, total strain after N passes is given with a simpler form:

$$\varepsilon = (N/\sqrt{3})[2(\cot(\Phi/2)] \qquad (2)$$

According to the last equation, very high equivalent strains can be obtained after several passes in ECAP processes. In addition to obtaining very high strains and strengthening, average grain sizes are considerably decreased in severe plastic deformation processes by high shear strains. Ultra fine grains are obtained by the process and the subject regarded in nano-structure applications. There are several articles about the grain size effects on the mechanical properties [1,2,3,4,5,6].

On the other hand, besides the achievements on mechanical properties, there are some problems about the ECAP dies especially having square and rectangular cross section as corner cracking in die assemblies due to very high stress concentration [3]. There are several works on the alternative die design to decrease frictional effects thus total loads, to facilitate the material flow around the corners, to use classical extrusion combining with an ECAP die [7, 8, 9, 10, 11, 12]. In order to overcome the buckling risk, punches are sometimes be made as short pieces and put into the dies orderly. In some cases channel cross sections are made as circular in order to minimize the notch effect and thus the crack formation [3].

In some recent works alternative die des are proposed and applied in order to eliminate cracking around die corners [13,14]. In the studies ECAP dies were made as multi pieces and placed in a die holder cylinder in order to keep them together during the process. Because of the dies have already been separated along the corner regions, there is no risk of cracking.

On the other hand, some approaches on the application of ECAP processing to cold pressure welding of same or different type materials are there in the literature [15,16].

In the presented study, 5083 Aluminum and Ms 58 Brass alloy strips having 2 and 4 mm thickness of 8 mm width were placed in 8x8 mm2 cross-sectioned ECAP die side by side and processed with single and double passes in order to model the metallic plating under cold pressure welding conditions.

2. MATERIAL AND METHOD

2.1. Die Geometry and Special Considerations

In the presented study, previously manufactured ECAP dies of article [14] with zero rounding off (Ψ = 0 in Fig.1a) and perpendicular channel (Φ = 90o) were used. According to the eq.2, equivalent strain in one pass is calculated as 115%. Channel cross sections equal to 8x8 mm2 and length of the channel is 60 mm. Considering the harsh frictional conditions and high pressure in the channel region, die parts are machined AISI H13 hot work tool steel, hardened at 1040oC and tempered at 600oC to 50 HRC hardness level. After the heat treatment, dies were polished before the tests. Punches were cut from 8x8 mm2 high speed tool steel cutters. Photos of the parts and the die assembly are given in Figure 2.

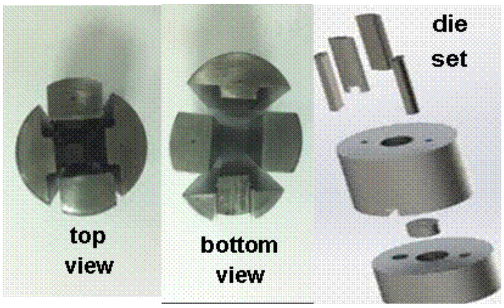

Fig. 2 Photographs of the separated die elements and the die assembly.

In the experimental work of the study, specimen were ECAPed using a 100 kN screw driven universal material testing machine with constant cross-head speed of 10 mm/sec. shown in Figure 3.

Figure 3. Experimental set-up

Specimen and die walls were lubricated prior to each test. After finishing the test, dies and ECAPed specimen were taken off from the die holder cylinder using ejector punches due to high blocking pressure between die parts and the holder.

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2.2. Experimental Study

Experimental work was done in two stages. In the first stage, square cross-sectioned 5083 aluminum specimens [17], were ECAPed in four passes, and in the second stage aluminum and brass stripes were ECAPed in two passes. Due to the low load capacity of the machine, cross sections of the test specimens and their lengths were machined as 8x8 mm^2 and 30 mm respectively.

During the upsetting period test loads increased sharply up to approximately 35 kN, and begun to decrease slightly due to decrease in the length of entrance(upset) channel as expected.

Hardness variation of the specimens was measured as using an EMCO Hardness tester shown in Figure 4 after each passes as Brinell Hardness scale with 2,5mm ball diameter $5D^2$ hardness load. Photos of some of ECAPed specimens are given in Figure 5 and hardness variation results are given in the diagram of Figure 6.

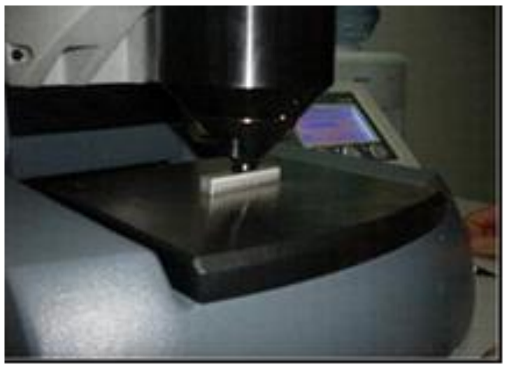

Figure 4. EMCO Hardness tester used for hardness measurements

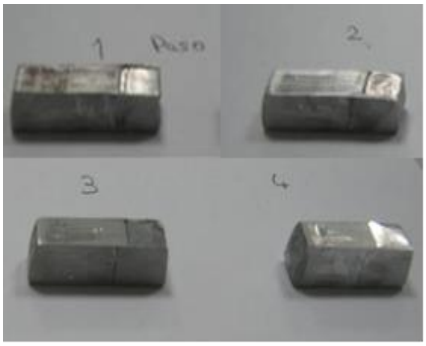

Figure 5. Examples of the ECAP specimens of several passes

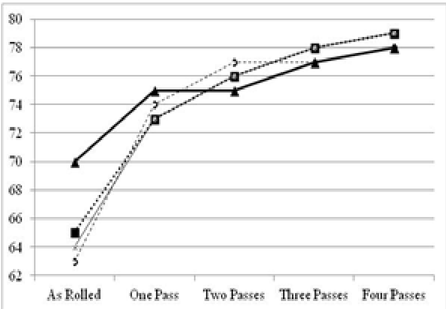

Figure 6 Specimens Hardness Variations in Brinell Scale

As it is seen in the Figure 6, ECAP processing increases sharply at the first pass approximately 16 percent and with the additional passes, hardness values goes to an asymptote of 80 HB. This tendency is harmonious with the literature.

In the second stage of the study, ECAP processing was tried to apply in cold pressure welding of two different thicknesses alloy strips having 8 mm width and 40 mm length. Before the ECAP processing, cold upsetting was applied to two 2 mm thickness strips between 8 mm width punches as shown in Figure 7. For 85 percent upset ratio, cold pressure welding was achieved as it was expected. Upset strips are shown in Figure 8.

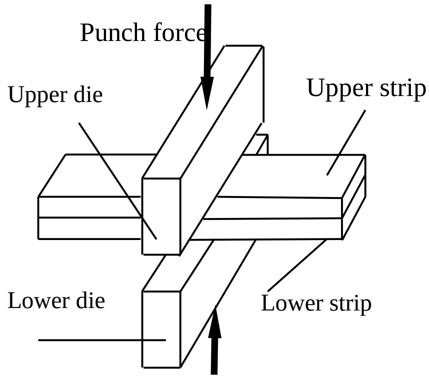

Figure 7. Strip upsetting die arrangement.

Figure 8. Upset specimens

After the cold upsetting, ECAP processing of strips were done. In this stage, four aluminum strips of two mm thickness were placed into the die, and full processed in one and two passes as in Figure 9.

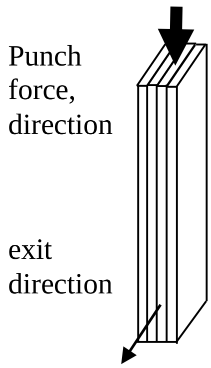

Figure 9. Strip ECAP'ing

Although some partial cold bonding is obtained for short specimens, almost any successful cold welding were not obtained. In Figure 10, some strip ECAP'ing photos are shown.

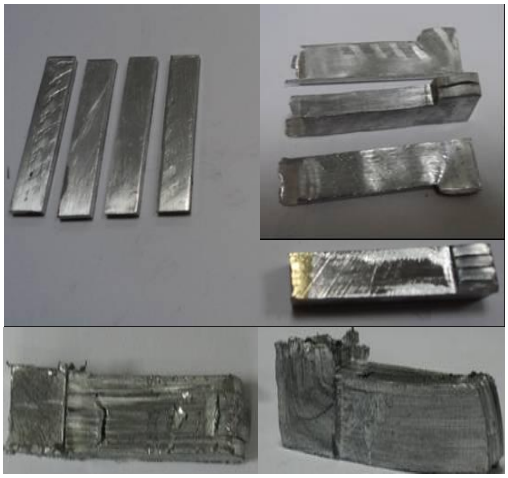

Figure 10. Strip ECAP'ing examples.

3. RESULTS AND DISCUSSION

In the first part of the presented study, ECAP processing of 8x8 mm2 cross-sectioned having 30 mm length 5083 aluminum rectangular specimens were processed up to four passes using separated dies. Hardness increase and material flow with those in the literature. There were no crack formation on the dies and the method of separated die manufacturing leads practical and long life dies.

On the other hand, in the second part of the study almost any success was obtained. Although some partial joints are observed, there should be some developments done. Choosing short specimen due to low force application capacity causes to fail in obtaining sharp corners on the exit section. As it can be seen in Figure 11, approximately 30o rounding off is occurred. This value causes to overall deformation ratio of the ECAP decrease down to 80 percent according to the eq.1. This situation acts as a negative factor in deformation process and weakens the cold pressure welding application.

Figure 11. Occurrence of root rounding off in ECAP process

In future work, new die arrangement will be done in order to increase the success capacity of the ECAP application in cold pressure bonding and metal plating.

4. ACKNOWLEDGEMENT

Authors wish to thank to Istanbul Aydin University Techno-center for the technical facilities and helps during the specimen preparations and experimental studies.

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